Micropalaeontological analyses of the Narzole core: biostratigraphy and palaeoenvironment of the late Messinian and early Zanclean of Piedmont (Northwestern Italy)

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ABSTRACT - Integrated biostratigraphic and palaeoenvironmental analyses of foraminiferal, ostracod and calcareous nannofossil assemblages are here presented for the late Messinian/early Zanclean succession of the Narzole borehole (Albese area, Piedmont, Northwestern Italy). The Narzole core is made of about 20 m of marine sediments and is stored in the collections of the Torino University, deposited at the Torino Regional Museum of Natural Sciences and until now represents the only documentation of the Messinian/Zanclean boundary (MZ) in the Albese subsurface. The uppermost Messinian “Lago-Mare” deposits yield reworked marine microfossils and a brackish ostracod assemblage representative of the Lastoxicorniculina djafarovi Zone, indicating their deposition in oligo-mesohaline shallow waters and the influx of Paratethyan faunas. The boundary between the post-evaporitic Messinian sediments and the overlying early Zanclean Argille Azzurre Fm. (AA) is marked by a 0.50 m thick barren arenitic layer, dark brown to black in its middle part, well correlatable to the black level recognized at the M/Z boundary in the nearby Moncucco quarry outcrop (Torino Hill). The Early Zanclean succession yields abundant microfossils, which document the MP11 (Sphaeroidinellopsis acme) and the MP12 foraminiferal zones, and the MNN12 calcareous nannofossil zone. Many bioevents recognized at Moncucco and on the Mediterranean scale are recorded in the studied succession: one sinistral coiling shift of Neogloboquadrina acostaensis, the Globorotalia scitula common occurrence (CO), the re-immigration of Siphonella reticulata, the Globorotalia marginata first common occurrence (FCO), the first influx of North Atlantic Deep Water (NADW) forms as Cibicidoides robertsonianus. Henryhowella asperrima and Oblitacythereis mediterranea firstly occurred in the MP11 zone, like in the Moncucco section, while in southern Italy and Mediterranean Pliocene sections they occurred at the base of MP1 2 biozone. Foraminiferal and ostracod assemblages document an epibathyal basin just from the early Zanclean. Fluctuations in water temperature and productivity are suggested by quantitative changes of warm water, oligotrophic surficial taxa (Globigerinoideas) versus intermediate water, eutrophic and phytoplankton grazers (N. acostaensis). A deepening of the basin during the MP11 is suggested by the increasing diversity of benthic foraminifers and of deep bathyal ostracods. All palaeoecological data suggest open marine circulation patterns in this sector of the Northwestern Italy during the MP11-MP12 Early Pliocene zones. This palaeoenvironmental interpretation is corroborated by the very high P/(P+B) ratio, the presence of mesopelagic planktonic foraminifers as Sphaeroidinellopsis spp., common to frequent deep cosmopolitan benthic foraminifers (Cibicidoides pseudoungerianus, Sphaeroidina bulloides, Uvigerina peregrina etc.), common bathyal ostracods (Argilloecia acuminata, A. kissamovensis, O. mediterranea, Pajenborchella iocosa, P. dimorpha, Xestoleberis progustata etc.), the rare discoasterids and ceratoliths (Ceratolithus acutus, Amoebolithus primus, A. delicatus), typical tropical open marine taxa, usually very rare in the Mediterranean Zanclean.

RAISSUNTO - (Analisi micropaleontologiche del sondaggio di Narzole: interpretazione biostratigrafica e paleoambientale del Messiniano superiore e Zanclean inferiore del Piemonte (Italia nord-occidentale)) - Il presente lavoro esume i risultati dello studio micropaleontologico integrato (foraminiferi, ostracodi e nannofossili calcare) condotto sui medesimi campioni della carota prelevata presso Narzole (Alba, Piemonte, Italia Nord-occidentale) nel 1975, nella quale Sturani ha descritto e illustrato il livello arenitico nero al limite Messiniano/Zancleano e in cui sono conservati circa 20 m di sedimenti marini. Il materiale di Narzole è catalogato nelle collezioni dell'Università di Torino, depositate presso il Museo Regionale di Scienze Naturali di Torino e rappresenta tuttora l'unica documentazione del limite Messiniano/Zancleano (MZ) nel sottosuolo dell'Albese. I sedimenti messiniani della facies di “Lago-Mare” contengono microfossili marini rimaneggiati e ostracodi salmastri indicativi della zona a Loxocorniculina djafarovi, che documentano condizioni di acque basse oligo-mesoaline e l'influsso di faune della Paratethys. Il limite tra i depositi post-evaporitici messiniani e le sovrastanti Argille Azzurre (AA) dello Zancleano inferiore è evidenziato da un livello arenitico da scuro a nero di 0.50 m di spessore, simile a quello presente al limite M/Z a Moncucco. Le associazioni a microfossili delle AA documentano le zone MP11 (Sphaeroidinellopsis acme) e MP12 a foraminiferali planctonici e la zona MNN12 a nannofossili calcarei. Molti bioeventi noti in area Mediterranea e segnalati a Moncucco sono stati riconosciuti anche nella successione di Narzole: un cambiamento della direzione di avvaligimento di Neogloboquadrina acostaensis, i successivi influssi/re-immigrazione di Globorotalia scitula e di Siphonella reticulata, la First Common Occurrence (FCO) di Globorotalia marginatae, i primi influssi di forme profonde, tipiche delle "North Atlantic Deep Water" (NADW), quali Cibicidoides robertsonianus. Henryhowella asperrima e Oblitacythereis mediterranea compaiono per la prima volta durante la zona MP11, come a Moncucco, mentre in Italia meridionale e in Mediterraneo la loro comparsa è segnalata alla base della zona MP12. I dati micropaleontologici documentano fondali epibathtici già a partire dalla base dello Zancleano. Fluttuazioni climatiche e della productività sono suggerite dalle variazioni quantitative dei taxa planctonici di acque superficiali, calde e oligotrofiche (Globigerinoideas) e delle forme di acque intermedie eutruffiche (N. acostaensis). L’aumento della diversità specifica dei foraminiferi bentonici e degli ostracodi suggerisce un ulteriore approfondimento del bacino e buone comunicazioni con il Mediterraneo durante le zone MP11 e MP12. Questa interpretazione è basata sull’elevato rapporto P/(P+B), sulla presenza di foraminiferi planctonici mesopelagici (Sphaeroidinellopsis spp.), sull’associazione a foraminiferi bentonici formati da taxa profonde e sottosommerse, Sphaeroidina bulloides, Uvigerina peregrina, Cibicidoides pseudoungerianus, Sphaeroidina bulloides, Uvigerina peregrina etc.), su rare forme ostracodiali (Argiloecia acuminata, A. kissamovensis, O. mediterranea, Pajenborchella iocosa, P. dimorpha, Xestoleberis progustata etc.), su rare forme discostieridiche e ceratolitiche (Ceratolithus acutus, Amoebolithus primus, A. delicatus), tipiche forme tropicali di mare aperto, generalmente molti rari nello Zancleano dell’area Mediterranea.

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INTRODUCTION

In the Messinian Symposium, yield at Erice (Sicily) in September 1975, Carlo Sturani, a researcher of the Torino University and a young emerging Italian palaeontologist, presented an original and detailed analysis of the Piedmont (Northwestern Italy) Messinian succession. Sturani described and figured a very abrupt contact at the Messinian/Zanclean boundary, documented in a borehole drilled near Narzole, in the Albese area (Piedmont, Northwestern Italy) (Figs. 1-2). Above the lacustrine clays of the Messinian Congeria facies, about one meter of coarse sands, dark brown to black in their middle 50 cm, was recorded underneath Early Pliocene marls, interpreted as open marine, outer neritic deposits on the basis of preliminary micropalaeontological analyses carried out by Mario Sampò. After the tragic death of Carlo Sturani in the gypsum quarry of Scaparoni in December 20, 1975, his communication at the Erice Seminar was published thanks to a record of his talk, edited by his wife and colleagues (Sturani, 1978). Studies of the core stopped and no micropalaeontological data were published.

The Narzole core was initially laid in the storage of the Institute of Geology, Palaeontology and Physical Geography of the Torino University, soon after it was relocated in the nearby University Museum of Geology and Palaeontology and then apparently it was lost. In 1980, thanks to a convention between the Piedmont Region and the Torino University, the rearrangement of the rich geological and palaeontological collections was undertaken by researchers and technicians of the Torino Regional Museum of Natural Sciences (TRMNS). After the move of the TRMNS to the present address, the collections reordering continued and the Narzole core was found in a temporary storage. After a careful rearrangement of the material (L.M. Gallo), the core is now definitely placed in Storage D9, drawers 12.5 to 12.10 of the TRMNS collections and represents the sediment interval between 6-26.80 m below the ground level (Fig. 3). On the basis of the procedures followed in the inventory of the TRMNS collections, the core was numbered as GEO.2459 and described in the “Catalogo delle collezioni geologiche e litologiche del Museo di Geologia e Paleontologia dell’Università di Torino” (p. 90) under the name “Collection 21 - Narzole core of Messinian sediments” (Gallo, 2004).

Up to now the Narzole core represents the only documentation of the Messinian/Zanclean boundary (M/Z) in the subsurface of the Albese region, where both the Messinian pre-evaporitic to post-evaporitic succession and the Zanclean marls and silts are well exposed (Sturani & Sampò, 1973), but the boundary is generally covered. Only recently it was detected in outcrops exposed along the Tanaro river (Pollenzo section, Clari et al., 2008), where studies are in progress.

Aim of the micropalaeontological analysis of the Narzole core is to complete the brief information given by Sturani (1978) and to compare these data with those of the recently studied coeval succession of Moncucco.
Torinese (Bicchi et al., 2002; Trenkwalder et al., 2008; Violanti et al., in press), in order to investigate the palaeoenvironmental evolution of the central Piedmont region at the Messinian/Zanclean boundary and in the early Zanclean. Moreover, this study wants to be a tribute to the late Torino University palaeontologists Carlo Sturani and Mario Sampò.

MATERIAL AND METHODS

As reported on the CNR technical report (courtesy F. Da Roit), the drill-hole was aimed to core the Messinian/Zanclean boundary (M/Z) and was drilled on a river terrace on the left side of the Tanaro river, near Cascina Torre, Narzole (Cuneo, Piedmont, Northwestern Italy) during January 1975, by the CNR technicians Walter Boltri and Francesco Da Roit, under the supervision of Carlo Sturani (Fig. 4). The core penetrated 0.50 m of anthropic soil, 5.20 m of alluvial coarse deposits, 18.40 m of Pliocene blue-grey bioturbated clayey marls, referable to the Argille Azzurre Formation (AA) (from 5.70 to 24.10 m below the ground level), a 0.50 m thick layer of arenitic sediments with small pebbles, dark brown to black in its middle, interpreted in the report as a palaeosoil (from 24.10 to 24.60 m) and finally 2.20 m of sands and clays referred to the Messinian (Congeria beds of Sturani, 1978, i.e. Lago-Mare facies). The drilling stopped at 26.80 m below the ground level. No erosional surfaces between the different lithologies were evidenced.

Twenty-six samples were analyzed from the Messinian/Zanclean succession at intervals ranging from 0.30 to 1.5 m and numbered with their depth below the ground level (m b.g.l.). Washing residues for foraminifer and ostracod analyses were prepared gently boiling the dry sediment with a small quantity of sodium carbonate to disaggregate the sediment, then washing the disaggregated material on the sieves set. Three fractions (>250 µm, 250-125 µm, and 125-63 µm) were obtained for each sample. Residues were dried at 50°C and weighted.

Foraminiferal taxonomy is according to Kennett & Srinivasan (1983) and Hemleben et al. (1989) for planktonic species, Agip (1982) and Van Morkhoven et al. (1986) for benthic species. The biostratigraphic scheme adopted here is that of Cita (1975a), emended by Sprovieri (1993).

Quantitative analyses of foraminiferal assemblages (D. Violanti) were carried out on total residues >125 µm of the Pliocene succession, split into aliquots of at least 300 well-preserved tests, in order to allow comparison with recent studies in the area (Violanti, 2005; Trenkwalder et al., 2008). The number of foraminiferal specimens per gram of dry sediment (FN/g) and the P/(P+B) ratio were calculated. Two indexes of specific diversity were measured separately for planktonic and benthic taxa: 1) species richness (S) as the total number of taxa for each sample; 2) Fisher’s diversity index (α) which is a measure of diversity taking into account the number of taxa as well as the number of specimens for each sample. These indices were calculated using the PAST ver. 1.77 Program (Hammer et al., 2008). A Planktonic Faunal curve was constructed by the algebraic sum of the percentages of warm-water oligotrophic indicators (positive values) (Globigerinoides spp., Globoturborotalita apertura group, including also G. decoraperta and rarer G. woodi, and Orbulina spp.) and of cold-water eutrophic indicators (negative values) (Globigerina bulloides group, including G. falconensis, Neogloboquadrina acostaensis dextral, scarce N. humerosa, Globorotalia scitula and Turborotalita quinqueloba).

All the ostracod valves present in residues >125 µm of each sample were picked and then identified (S. Trenkwalder); their taxonomy is according mainly to Bonaduce et al. (1976), Abate et al. (1993) and Aiello et al. (1996). Species were counted following the Normalized Method (Mana & Trenkwalder, 2007): all the grown-up valves were counted and the number of minimum certain individuals was calculated as the sum
of complete carapaces plus the highest number of valves (left or right). For each sample, the number of species and the number of minimum certain individuals were calculated; the presence of juvenile forms was just pointed out.

Calcareous nannofossil analyses (F. Lozar) were performed on smear slides prepared according to standard methods and studied on light microscope under polarized light (transmitted light and crossed nicols) at 1250X magnification. Abundance data of nannofossil taxa were collected counting five hundreds specimens per sample; helicoliths were counted among 50 specimens of the group; discoasters and ceratholiths on 2-4 mm² of area as already established in previous works (Backman & Shackleton, 1983; Rio et al., 1990). Taxonomy is according to Perch-Nielsen (1985), Rio et al. (1990), Young (1998) and Raffi et al. (2003). The biostratigraphic scheme here adopted is that of Rio et al. (1990) for the Mediterranean region.

RESULTS

Grain size and composition

Percentages of the total >63 μm fraction are very high in the Lago-Mare samples and reach their maximum at 24.4 m b.g.l., in the black layer. Samples collected from the AA showed very low grain size percentages, only in the upper sample at 7 m b.g.l. the total >63 μm fraction was greater than 3% (Fig. 5). Terrigenous components (quartz grains, green schist debris, micas, pyrite aggregates) are dominant in the Lago-Mare sediments. The black layer is composed of a terrigenous fraction (quartz and lithic fragments of metamorphic rocks) with subordinate intrabasinal grains (glaucony and phosphates). It is totally homogenised, devoid of fossils and very rich in organic carbon. The terrigenous content is very scarce in most of the AA, it is common only in the lowermost and uppermost samples of the Pliocene succession.

Foraminiferal specimens are frequently diagenized in the Lago-Mare samples, whereas tests are very well preserved in most of the AA assemblages. Foraminifers and calcareous nannofossils are abundant in the AA succession, ostracods, echinoids, mollusk fragments, and vegetal debris are rare to common. Fish debris (otoliths, teeth, and bones) are rare.

Micropalaeontological data

LAGO-MARE ASSEMBLAGES. Samples from 26.8 to 25.7 m b.g.l. contain frequent but poorly preserved planktonic foraminifers, mainly represented by Miocene to Pliocene taxa (Globigerina bulloides, Globigerinella obesa, Globigerinoides obliquus, Globorotalia gr. scitula, Orbulina universa, Neogloboquadrina acostaensis (dominantly sinistral) and Turborotalita quinqueloba). Benthic foraminifers are extremely rare. Some Tortonian to Messinian species, as Globorotalia sutureae, are also present. The same samples contain few valves of the...
ostracod *Cyprideis agrigentina*. Calcareous nannofossil (CN) assemblages are quite abundant, but consist mainly of reworked and poorly preserved Upper Cretaceous, Oligocene and Lower and Middle Miocene taxa (*Watznaueria barnesae*, *Eiffellithus turriseiffeli*, *Micula decussata*, *Zygrhablithus bijugatus*, *Dictyoococites bisectus*, *Helicosphaera euthratis*, *H. walbersdorfenensis*, *Sphenolithus heteromorphus*, *Coccolithus mitopelagicus* among others). No typical Messinian CN is present. Sample at 25.4 m b.g.l., just below the black layer, is barren of foraminifers and ostracods and contains only very rare CN specimens, consisting mainly of dwarf placoliths (*Helicosphaera carteri*, *Coccolithus pelagicus*, *Sphenolithus abies*, *Reticulofenestra* sp.).

**ARGILLE AZZURRE FORMATION ASSEMBLAGES**. Microfossil preservation in the blue-grey clayey marls (AA) was generally good, only at 7.0 m b.g.l. the preservation is moderate and biogenic fragments are frequent.

The FN/g (number of foraminiferal tests per 1 gram of dry sediment) (Fig. 5) displays low values, below 500 tests/g in the lowermost samples, shows an increase between 22.3-20.1 m b.g.l., then a strong abundance peak at 16.4 m b.g.l. (maximum 2572.39 FN/g) and approximated 1000 FN/g at 13.9 and 12.8 m b.g.l. Decreasing values are registered in the upper interval.

The P/(P+B) ratio shows very high percentages (70-80%) within the lowermost samples up to 21.7 m b.g.l. (Fig. 5). Values become slightly lower upwards, ranging between 60-70% up to 11.8 m b.g.l. and then display some stronger variations, decreasing to about 40% at 13.9 and 12.8 m b.g.l.

Planktonic foraminiferal diversity indices are expressed as the species richness (S) and the Fisher’s α index and display low variations throughout the succession. The species richness (S) (=species number) ranges between 13-19, while the Fisher’s α index is lower than 5 (Fig. 5).

Benthic diversity indices register wide variations. The benthic species richness (S) is comprised between 40-60 just from the lowermost samples, the benthic Fisher’s α index is low in the basal samples, increases upwards (Fig. 5), and shows two peaks at 22.3 and 15.4 m b.g.l.

Planktonic foraminifera

*Sphaeroidinellopsis* spp. are recognized in the interval from 22.7 to 20.7 m b.g.l. and at 8.0 m b.g.l., some large specimens are present. *Sphaeroidinellopsis* spp. reach percentages >1% only at 22.3 m b.g.l. (Fig. 6).
Rare, small tests of *Globorotalia margaritae* occur from 19.3 m b.g.l., but large specimens of *G. margaritae evoluta* (Cita, 1973, 1975b) become more common at 10.6 m b.g.l. (2.68%) and are present in the uppermost samples.

The warm-water, oligotrophic genus *Globigerinoides* (Hemleben et al., 1989) is represented by frequent *G. extremus* and *G. obliquus*, common to rare *G. gomitolus*, *G. ruber*, *G. sacculifer*, and *G. trilobus*. *Globigerinoides* spp. display values lower than 20% in the lowermost sample (minimum 10%, 20.1 m b.g.l.) (Fig. 6) and become dominant in most of the following planktonic assemblages, attaining more than 40% of the planktonic assemblage at 12.8 m b.g.l. A strong decrease is recorded at 10.6 m b.g.l. (18%).

Warm-water oligotrophic taxa include also *Orbulina universa* (Hemleben et al., 1989) and the *Globoturborotalita apertura* group (*G. apertura*, *G. decoraperta*, *G. woodi*) (Serrano et al., 1999) (Fig. 6). *Orbulina universa* is in general scarce (5-10%), its specimens are large and frequent only in few lower samples, with its frequency maximum at 22.3 m b.g.l. (37.74%). The *Globoturborotalita apertura* group is frequent to abundant, ranging between 25-40% in most assemblages but shows few strong variations, decreasing to about 10% at 22.3 and 10.6 m b.g.l.

The cold-water, eutrophic taxa are mainly given by the *Globigerina bulloides* group (*G. bulloides*, *G. falcondensis*) and by Neogloboquadrinids (dextral coiling *Neogloboquadrina acostaensis*, rare *N. humerosa*) (Pujol & Vergnaud Grazzini, 1995; Serrano et al., 1999). Percentages of the two taxa are always lower than 30% (Fig. 6). The *Globigerina bulloides* group reaches its maximum in the middle part of the succession, whereas the phytoplankton grazers *Neogloboquadrinids* (Hemleben et al., 1989) and the *Globigerinoides* group reach their maximum at 22.3 m b.g.l. (Fig. 7). Among the less common taxa recognized from the lowermost samples are *Oridorsalis umbonatus* (which attains its higher frequencies (about 4%) at the very base of the succession), *Sigmolaopsis schlumbergeri*, and *Gyroidinoides neosoldanii*, more common in the upper samples. *Siphonina reticulata* is absent in the lower samples, firstly occurs at 20.1 m b.g.l., is common (8-9%) up to 13.9 m b.g.l. and decreases in the uppermost samples. Other less frequent taxa, absent at the succession base, appear in the following order: *Anomalinoeades helicus* and *Uvigerina longistriata* from 23.4 m b.g.l., *Karreriella gaudeynoides* from 22.7 m b.g.l., *K. bradyi* from 22.3 m b.g.l., *Cibicoides robertsonianus* from 19.3 m b.g.l., *C. kullenbergi* from 18.6 m b.g.l. (Fig. 7), *Cylindroclavulina rudis* from 17.6 m b.g.l., *Anomalinoeades granosus* from 8.9 m b.g.l., *A. ornatus* is recognized in the counted assemblage only in the uppermost sample. *Nodosariidae* are generally common, abundant at 22.3 m b.g.l. (about 25%) (Fig. 7) and represented by many species of *Dentalina* (*D. communis*, *D. leueuminiformis*, *D. mucronata*), *Lenticulina* (*L. cultrata*, *L. echinata*, *L. rotulata*, *L. vitrea*, etc.), *Marginulina* (*M. crebricosta*, *M. spinulosa*, etc.), *Nodosaria* (*N. longisca*, *N. raphanus*, etc.), by *Chrysalagonon obliquatum*, *Dimorphina tuberosa*, *Mucronina gemina*, *Planularia auris*, *Saracenaria italica*, *Vaginulina legumen*, and *Vaginulinospis carinata*. Many other outer neritic to epibathyal taxa, as *Amphicorina* spp., *Bigrerina nodosaria*, *Eggerella bradyi*, *Gyroidinoides laevigatus*, *Heterolepa bellincioni*, *H. dertonensis*, *Martinottiella communis*, *M. perparva*, *Melonis padanum*, *M. soldanii*, *Oridorsalis stellatus*, *Uvigerina pygmaea*, and *U. rutilla* are recognized in most samples. *Birinalina* spp. (*B. dilatata*, *B. spathulata*) and shallow water taxa (*Cibicoides lobatulus*, *Elphidium spp.*, *Neocomorbinia terquemi*, and *Rosalia* spp.) are very rare or absent in most samples.

**Ostracods**

A total of 35 ostracod species belonging to 21 genera has been identified in the counted assemblages of the Pliocene A.A. The number of species throughout the succession (Fig. 8) is relatively low (less or equal than 22 per sample); the curve representing the number of minimum certain individuals (Fig. 8) shows almost the
same trend as that of the number of species and reaches its maximum in the interval between 22.7-19.3 m b.g.l., where the diagram shows values >100 for sample. The main taxa identified in Pliocene sediments are: Argilloecia acuminata, A. kissamovensis, Bythocypris bosquetiana, B. obtusata producta, Cytherella gibba, C. russoi, C. vulgatella, Henryhowella asperrima, Krithe compressa, K. iniqua, Oblitacythereis mediterranea, Paijenborchella iocosa, and Parakrithe dimorpha.

Moreover, Argilloecia acuminata, A. kissamovensis, B. obtusata producta, Henryhowella asperrima, Krithe compressa, K. iniqua, Oblitacythereis mediterranea, Paijenborchella iocosa, and Xylocythere producta occur from 23.7 m b.g.l., Bythocypris bosquetiana and Parakrithe dimorpha from 23.4 m b.g.l., Cytherella gibba, C. russoi, C. vulgatella, and Xestoleberis prognata from 22.7 m b.g.l. (Fig. 8).

Calcareous Nanofossils

Within the AA samples, calcareous nanofossil reworking is very low (Fig. 9); rare specimens of Ceratolithus acutus have been recorded, whereas specimens of Triquetrorhabdulus rugosus, usually present at the very base of the Zanclean (Di Stefano, 1998, Castradori, 1998), do not occur. Upwards in the section, calcareous nanofossil assemblages are very diversified and dominated by reticulofenestrids, together with helicoliths (the only species being Helicosphaera carteri); minor components of the assemblage are discoasterids and ceratholiths (C. acutus, Amaurolithus primus, A. delicatus), typical tropical open marine taxa, usually very rare in the Mediterranean Pliocene. Helicosphaera sellii with pores larger than 1.5 μm (Raffi et al., 2003) has not been recorded in this material. Directly above the black layer, a species of Reticulofenestra with a circular outline (Reticulofenestra pseudoumbilicus - circular outline - in Castradori, 1998; Reticulofenestra zancleana, according to A. Di Stefano, pers. comm.) occurs. This taxon ranges from 6 to 8 μm in diameter, has an open squared central area and is common in the assemblage up to 19.3 m b.g.l., upward in the core this taxon becomes rare or absent (Fig. 9). Moreover, the lowermost Pliocene samples are characterized by high but discontinuous abundances of R. minuta up to 19.3 m b.g.l. Abundance peaks of S. abies are recorded at 19.3, 15.4 and 11.8 m b.g.l. Braarudosphaera bigelowi, usually very rare or absent, is locally present in low abundances in discrete layers (18.6, 15.4, and 11.8 m b.g.l., Fig. 9).
DISCUSSION

Upper Messinian Lago-Mare assemblages

Marine assemblages of Lago-Mare sediments contain long-ranging and Tortonian to Messinian foraminiferal taxa such as *Globorotalia suterae*, Cretaceous to Miocene calcareous nannofossils, which are interpreted as reworked from older pre-evaporitic sediments. Ostracods are characterized by the presence of *Cyprideis agrigentina*, a taxon restricted to the Messinian (Decima, 1964; Colalongo, 1968), common in the Lago-Mare sediments of many Sicilian sections (Decima & Sprovieri, 1973; Bonaduce & Sgarrella, 1999). *C. agrigentina* was a taxon characteristic of brackish waters (Rouchy et al., 2007), which inhabited waters probably not deeper than 50 m (Van Harten, 1990) and indicates a shallow-oligohaline palaeoenvironment (Grossi et al., 2008) for the uppermost Messinian deposits of the Narzole core. This taxon, according to Cipollari et al. (1999a) and to Gliozzi (1999) is typical of the *Loxoconcha djafarovi* Zone, a biozone originally defined by Sissingh (1972) and re-described by Carbonnel (1978), which approximates the Miocene/Pliocene boundary. According to Gliozzi et al. (2006) the *Loxocorniculina djafarovi* biozone includes the Lago-Mare Biofacies 2 of Bonaduce & Sgarrella (1999) and the Paratethys Assemblage (*Loxoconcha djafarovi* assemblage) of Iaccarino & Bossio (1999). *Cyprideis agrigentina* represented an Italian Lago-Mare species with Paratethyan affinity (Cipollari et al., 1999b; Orszag-Sperber, 2006; Gliozzi et al., 2007; Ligios & Gliozzi, 2008) that indicates a post-evaporitic Messinian age. These assemblages are well comparable to those of the Lago-Mare deposits of the Moncucco quarry succession, in which also characteristic lower Messinian species such as *Globorotalia conomiozea* (LO 6.52 My, Gradstein et al., 2004) and *G. nicolae* (LO 6.72 My, Hilgen et al., 1995) were recovered (Trenkwalder et al., 2008; Violanti et al., in press). Reworking of marine microfossils is widely documented in late Messinian brackish Lago-Mare sediments (Ryan et al., 1973; Cita et al., 1978; Spezzaferri et al., 1998; Iaccarino et al., 1999; Irace et al., 2005; Pierre et al., 2006; Rouchy et al., 2007; Grossi et al., 2008). No *in-situ* open marine forms, that could suggest normal marine episodes or influxes, have been detected in the uppermost Messinian sediments.

Early Zanclean Argillo Azzurre Fm. Assemblages

The Pliocene succession cored at Narzole could be dated to an interval encompassing the Zanclean MP11 and MP12 zones on the basis of the occurrence of *Sphaeroindellopsis* spp. and *Globorotalia maragritae*.
cycles 2-3, near the base of the lithological cycles 1-2, the second and younger between Capo Spartivento section (Southern Italy) (Di Stefano et al., 1996). In the Narzole core pertains to the MNN12 zone. The acme interval (5.29-5.20 My, Gradstein et al., 2004), marker of the MPl2 biozone. This taxon was already recorded in the Moncucco quarry section (Trenkwalder et al., 2008), where it occurred in the lower part of the core, as in the Moncucco quarry (Trenkwalder et al., 2008). N. acostaensis is essentially right-coiled. Left coiling specimens, even if occurring as a minor component, are present only in the first few decimeters above the BL. Their occurrence could approximate one of the coiling shifts detected by Di Stefano et al. (1996). Also the occurrence of Ceratolithus acutus just above the black layer and the absence of Triquetrorhabdulus rugosus suggest that the very basal Zanclean could be missing in the section.

b) the abundance peak of Globorotalia scitula dextral, found at 22.7 m b.g.l. The CO (Common Occurrence) of Globorotalia scitula dextral, reported as a “delayed invasion event” in the basal Zanclean of the Western Mediterranean was correlated to cycle 6 (Iaccarino et al., 1999).

c) the occurrence of Oblitacythereis mediterranea among Pliocene ostracods is of stratigraphic importance, because the taxon had its first appearance only in the Zanclean (Early Pliocene) and extended to the Middle Pliocene of the entire Mediterranean area (Ilani et al., 2008). Moreover, at Narzole, Henryhowella asperrima and Oblitacythereis mediterranea firstly occurred in the MPl1 biozone since the basal sample (Fig. 8), like in the Moncucco section (Trenkwalder et al., 2008), while in Pliocene sections of the Ionian Calabria (Ciampo, 1992), in Eraclea Minoa in Sicily (Barra et al., 1998) and in Site 654A, ODP Leg 107, drilled in the Tyrrhenian Sea (Colalongo et al., 1990) they occurred later, at the base of MPl2 biozone.

d) the occurrence of a medium size circular Reticulofenestra species, already observed in deep-sea sediments of the Eastern Mediterranean (Reticulofenestra pseudoumbilicus circular outline, Castradori, 1998; R. zancleana, A. Di Stefano, pers. comm., 2008) within the lower part of the core (from 23.7 to 19.3 m b.g.l.). Its biostratigraphic value has recently been proposed and tested in other basal Zanclean sediments of both Eastern and Western Mediterranean DSDP and ODP Sites (Di Stefano & Sturiale, 2008), were its LCO (Last Common Occurrence) is located just below the MPl1/MPl2 boundary (A. Di Stefano, pers. comm., 2008).

Sedimentological characteristics, microfossil (foraminifers, ostracods, and calcareous nannofossils) assemblages composition and fluctuations suggest various changes in the palaeoenvironmental parameters during the deposition of the AA. Four intervals can be evidenced in the Pliocene succession of Narzole, from the bottom to the top and sedimentation rates for three of them, well defined by the biostratigraphic data, were calculated with the aim to compare with sedimentation rates of other coeval Mediterranean successions. Zanclean sedimentation rates from the Messinian/Zanclean boundary, 3.33 My (Van Couvering et al., 2000), to the G. margaritae LO (Last Occurrence), 3.9 My (Cita et al., 1999), were low in the entire Mediterranean deep-sea records, ranging from 1 cm/1000 y to 11 cm/1000 y (Cita et al., 1999). The abrupt sea-level rise at the Pliocene transgression strongly modified the equilibrium between erosion and deposition and only after the G. margaritae LO the terrestrial input increased, leading to higher sedimentation rates. In the Moncucco T. quarry,
Trenkwaldler et al. (2008) calculated a mean sedimentation rate of 4.6 cm/1000 y for the MP11 time interval, documented in the outcrop by about 11.5 m of AA and very similar to the values calculated from drill sites in the Alboran Sea and the Balearic Basin (Cita et al., 1999). A lower value of 1.66 cm/1000 y was obtained at Moncucco T., for the entire time interval from 5.33 My to 3.9 My, but it was probably biased by non-detectable sedimentary hiatuses in the MP12 and MP13 zones.

1) - From 5.33 to 5.29 My (M/Z boundary, 24.1 m b.g.l. - base of the Sphaeroidinellops acme 22.7 m b.g.l.).

This time interval of 0.04 My is documented by about 1.4 m of AA (Fig. 5) and a sedimentation rate of 3.5 cm/1000 y was calculated, excluding the still undated BL, marking the Messinian/Zanclean boundary. If the BL was included, the sedimentation rate would increase to 4.75 cm/1000 y. Terrigenous debris (quartz grains, micas, rock fragments) are rather common, suggesting a continental input. Foraminiferal number per 1 gram of dry sediment (FN/g, Fig. 5) was low, whereas the P/(P+B) percentages were very high, ranging between 70-80%. Planktonic diversity indices are uniformly rather high, ranging between 70-90%.

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The rather poorly diversified lowermost benthic foraminiferal assemblages yield common to frequent outer neritic to epibathyal taxa (>10°C, Benson, 1977) and close to- or below the thermocline, such as the phytoplankton grazers Neogloboquadrinids (Fairbanks & Wiebe, 1980; Kennett et al., 1985). Turborotalitata quinqueloba, inhabiting surficial cool eutrophic waters (Hemleben et al., 1989) is here scarce. The Planktonic Faunal curve (Fig. 6) shows very low positive values. This pattern suggests temperate to warm-temperate waters and rather high primary productivity. Also the high abundance of R. minuta in the sediments overlaying the black layer suggests high nutrient levels in the upper water column, as already hypothesized for the pre-evaporitic Messinian (Negri & Villa, 2000; Lozar et al., in press).

The rather poorly diversified lowermost benthic foraminiferal assemblages yield common to frequent outer neritic to bathyal taxa (Cibicidoides pseudoungerianus, Bulimina minima, Planulina ariminensis, Sphaeroidina bulloides, Uvigerina peregrina, etc.) (Bolotovskoy & Wright, 1976; Murray, 2006). They were dominated by the cosmopolitan Cibicidoides pseudoungerianus (Van Morkhoven et al., 1986), usually considered to be epifaunal (Jorissen, 1987), doubtfully oxyphilic (Kouwenhoven, 2000) and preferential of well-oxygenated bottoms under high organic carbon fluxes (Woodruff, 1985; Jones, 1996; Murgese & De Deckker, 2005). Also spinose buliminids (mainly Buliminina minima), considered to be infaunal, adapted to low oxygen and/or high organic matter content (Corliss 1985; Murray, 2006) are frequent. Both the shallow infaunal Sphaeroidina bulloides (Corliss, 1985; Fontanier et al., 2006), frequent in high productivity slope areas influenced by seasonal input or coastal upwelling (Licari & Mackensen, 2005), and Planulina ariminensis, epifaunal, characteristic of well-oxygenated conditions (Kouwenhoven & Van der Zwaan, 2006), widespread on deep outer neritic to epibathyal bottoms (Wright, 1978; Van Morkhoven et al., 1986) are common. The shallow infaunal Uvigerina peregrina, preferential of high productivity (Jorissen, 2000; Loubere & Fariduddin, 2002) and U. pygmaea, followed by U. longistriata, and U. rutila, represent only less than 5% of the lowermost benthic assemblages. Oridorsalis umbonatus, an epifaunal taxon, preferential of low organic carbon fluxes (Mackensen et al., 1985), frequent in the lowermost Zanclean successions of the central Mediterranean area (Barra et al., 1998; Iaccarino et al., 1999) is rather common (about 4%) only in this interval. Gavelinopsis praegeri and Eponides tumidulus, recorded from the bathyal Mediterranean (Parker, 1958) and from bottoms influenced by high seasonal input of phytodetritus (Altenbach et al., 2003) are present in the finest fraction with lower frequencies than registered in the basal Zanclean of Moncucco (Trenkwaldler et al., 2008). Benthic assemblages dominated by S. bulloides and Gavelinopsis translucens (very close to G. praegeri) have been inferred to represent the fauna associated with the Oxygen Minimum Water in the Gulf of Mexico Late Pleistocene, in a depth range of about 450-670 m (Denne & Sen Gupta, 2003).

Ostracods are represented by low number of species and of individuals (Fig. 8). The oldest Zanclean ostracod assemblages are characterized by the presence, among others, of: Argillloecia acuminata (found in the Mediterranean down to 2600 m, Bonaduce et al., 1983). Bythocypris bosquetiana (described in the sediments of the Atlantic-Mediterranean area from 150 m to 3381 m, Aiello et al., 2000), Bythocypris obtusata producta (a taxon with a bathyal distribution, Bertini et al., 2008). Krithe compressa (living in the South China Sea at depth of 900 m, Whatley & Quanhong, 1993), Pajtendornchella icosa (living in the South China Sea at depth greater than 500 m, Keij, 1966), Parakrithe dimorpha (described in Italy in epibathyal Pliocene sediments (Aiello et al., 2000; Aiello & Barra, 2001). Also the presence of Oblacythereis mediterranea (considered an inhabitant of the transitional facies between psammospheric and shelf assemblages, Benson, 1978 and Ilini et al., 2008), upper bathyal thermospheric ostracod found in the Mediterranean between 300 and 1000 m depth, with an optimum between 400 and 600 m at bottom temperatures >10°C, Benson, 1977) suggests a deep palaeoenvironment.

At the base of the Zanclean succession, both foraminiferal and ostracod assemblages suggest open-marine conditions and upper epibathyal bottoms, probably not deeper than 500-700 m, for the rareness of deep bathyal taxa. Planktonic foraminiferal assemblages, in which warm oligotrophic and cool eutrophic planktonic taxa are nearly equally represented, suggest a temperate
or warm-temperate climate. A rather high seasonal productivity could be inferred based upon the frequencies of Neogloboquadrina acostaensis, Globigerina bulloides and is corroborated by the common presence of Sphaeroiodina bulloides, Bulimina minima, Gavelinopis praegeri, and Eponides pusillus in the benthic assemblage. Well-oxygenated or only moderately disaerobic bottom seem to be documented by the common epibenthic taxa (Cibicidoides pseudoungerianus, Planulina ariminensis) and by the low percentages of stress-tolerant taxa as Uvigerina peregrina and B. minima, species adapted to high organic content and low oxygen level (Schönfeld & Altenbach, 2005), as in the Moncucco section (Trenkwalder et al., 2008). The strong bottom disaerobic conditions registered in the early Zanclean of Capo Rossello (Barra et al., 1998; Sgarrella et al., 1999) would have not affected the northern Piedmont basin. A good bottom oxygenation has been documented in other sites of the Mediterranean area (Orszag-Sperber & Rouchy, 1979; Spezzaferri et al., 1998; Pierre et al., 2006), and different sedimentary situations, influenced by local palaeomorphologies, developed during the deep-sea flooding, rapidly extending to the entire Mediterranean basin.

2) - From 5.29 My to 5.20 My (base to top of the Sphaeroiodinellopsis acme).

About 2 meters of AA, from 22.7 to 20.7 m b.g.l., represent the time interval of 0.09 My and a mean sedimentation rate of 2.22 cm/1000 y was calculated. Residues are almost totally biogenic. Foraminiferal assemblages are characterized by increasing FN/g, very high P/(P+B) ratio, a peak of benthic Fisher’s z index (Fig. 5), the maximum abundance of Sphaeroiodinellopsis spp. and a frequency peak of Globorotalia scitula (Fig. 6). Warm water oligotrophic taxa such as Globigerinoides spp. and the Globorotaliala apertura group show higher values than in the lowermost samples and Orbulina spp. attain here their maximum. A concurrent decrease occurs in the cold water, eutrophic taxa. The Planktonic Faunal curve evidences the fluctuation toward warmer, oligotrophic conditions in the water column (Fig. 6). More temperate or eutrophic conditions were registered in the same interval at Moncucco (Violanti et al., in press), where Neoglabroquadrinids and G. scitula reached higher percentages. At Narzole, a lower productivity in the water column and/or a deeper thermocline in the photic zone could be inferred in comparison with Moncucco. The quantitative importance of deeper-dwelling taxa, occurring within and below the thermocline in association with the chlorophyll maximum was reduced, whilst the shallower-dwelling forms such as Globigerinoides spp. became quantitatively more important (Thunell et al., 1983). Benthic foraminiferal assemblages display lower frequencies of Cibicidoides pseudoungerianus and Planulina ariminensis, whereas percentages of Uvigerina peregrina increase to about 10-15%. Some benthal taxa such as Karreriella bradyi, Anomalinoïdes helicinus, and K. gaudryinoides firstly occur. The Nodosariidae reach their highest abundance in this interval (Fig. 7). Also the ostracod diversity and abundances increase, the number of individual here attains its maximum, Argilloecia kissamovensis, A. acuminata, Cytherella spp., Pajienborchella icosa, P. dimorpha, and Oblitacythereis mediterranea are frequent and Xestoleberis pronitra (a taxon living in bathyal environments, whose evaluated minimum palaeodepth corresponds to 600-800 m according to Abate et al., 1994) firstly occurs. All these data document the increasing assemblages palaeobathymetry and faunal diversity related to the progressive repopulation of the Mediterranean basin by deep bathyal Atlantic taxa (Spezzaferri et al., 1998).

3) From 5.20 My to 5.08 My (top Sphaeroiodinellopsis acme-G. margaritae FCO).

About 10.10 meters of AA, from 20.7 to 10.6 m b.g.l., represent a time interval of 0.12 My and a mean sedimentation rate of 8.4 cm/1000 y was calculated. Residues are always biogenic. The FN/g showed wide fluctuations, between very low values in the lower part of the interval, a peak in its middle and again decreasing numbers in the upper samples. The P/(P+B) ratio slightly shallows to 60/70% and also the P and B diversity indexes display repeated fluctuations, often in negative correlation with the FN/g trend (Fig. 5). Planktonic foraminiferal assemblages are characterized by the very rare and sporadic occurrence of small specimens of Globorotalia marginata and by a nearly progressive and cyclical increase of Globigerinoides spp. The cyclical astronomically forced frequency fluctuations of Globigerinoides spp. registered in Zanclean deep sea successions (Sprovieri, 1993) are also evident in this interval, even if the samples distance was rather large. The Globigerina bulloides trend is opposite to that of Globigerinoides spp., whereas a negative correlation is evident between the Globorotaliala apertura gr. and Neoglabroquadrinids curves (Fig. 6). The Planktonic Faunal curve suggests dominantly warm, oligotrophic water conditions, as documented in the same interval of the Moncucco section (Trenkwalder et al., 2008). Nevertheless, in the Narzole core short fluctuations of temperate or cooler, more eutrophic conditions are evidenced by the frequency increases of the upper intermediate dwellers tropical Neoglabroquadrinids (Keller, 1985).

Frequency of Uvigerina peregrina and Bulimina minima, shallow and intermediate infaunal detritivorous taxa, adapted to high organic content and low oxygen level (Van der Zwaan et al., 1988; Schönfeld & Altenbach, 2005) increase and show opposite trends to the epifaunal and oxyphilic Cibicidoides pseudoungerianus, correlated to high organic carbon fluxes (Murgese & De Deckker, 2005). In this interval, Siphonina reticulata firstly occurs and becomes common. S. reticulata was inferred to be a Mediterranean quasi-endemic form (Sgarrella et al., 1997, 1999), indicative of Early Pliocene Mediterranean Intermediate Water (EPMW) and its re-immigration in the Mediterranean appears to be a nearly synchronous event in the Mediterranean basin (Spezzaferri et al., 1998; Iaccarino et al., 1999; Pierre et al., 2006; Rouchy et al., 2007), correlated to the lithological cycle 6 (Di Stefano et al., 1996). The S. reticulata occurrence was also documented in the Moncucco section at a nearly similar level in the AA than in the Narzole core and could document the influx of
EPMIW into the Northwestern Italy as well as the connections with the Mediterranean basin during the early Zanclean. Other benthal species (Cibicidoides kullenbergi, C. robertsonianus, C. rudis, and Eggerella bradyi) add to the benthic assemblages, supporting the previous hypothesis. In particular, C. robertsonianus is interpreted as a typical NADW (North Atlantic Deep Water) form, indicative of a deep oceanic-type circulation in the Mediterranean early Zanclean (Hasegawa et al., 1990; Pierre et al., 2006). Percentages of benthic foraminifers decrease in the upper part of this interval, as the ostracod numbers of species and of minimum certain individuals. Argilloecia kissanovensis, Krithe iniqua, Oblitacythereis mediterranea, Pajienborchella iocosa, and Parakrithe dimorpha strongly decrease in abundance upwards. The concurrent frequency peaks of Uvigerina peregrina, Bulimina minima, and Bolivina spp. suggest episodes of higher organic carbon fluxes and/or an increasing availability of organic matter at the bottom.

4) From 5.08 My (G. margaritae FCO) to the top of AA.

About 4.10 m of AA, from 10.6 to 6.5 m b.g.l., represent the MP12 foraminiferal zone and the upper MNN12 calcareous nannofossil zone. The markers of the upper limits of these zone are absent, excluding the presence of the MP3 and MNN13/14 zones and there are not events that could indicate the extension of the interval. Nevertheless, the micropalaeontological composition and fluctuations of more common taxa are in positive correlation with assemblages of the 6.5 m thick MP12 sediments of the Moncucco section (Trenkwalder et al., 2008) and could represent almost entirely the same interval.

Foraminiferal assemblages show very low FN/g values. Warm water, oligotrophic planktonic taxa are often dominant, leading to a Planktonic Faunal curve with generally positive values. Nevertheless, abundance peaks of Neogloboquadrinids are registered in concomitance with the FCO of Globorotalia margaritae and in the upper samples and document brief fluctuations toward more eutrophic conditions and/or increased primary productivity. Only few benthal taxa (Anomalinaoides granosus, A. ornatus) add to the well-diversified benthic foraminiferal assemblages. Bulimina minima shows a slight progressive increase and Siphonina reticulata has strong abundance fluctuations (Fig. 7). The trend to a reduction in ostracod diversity, observed in the previous interval, becomes more evident (Fig. 8). The co-occurrence of Argilloecia acuminata with A. kissanovensis, Cythereopteron pinarense, Siphonina reticulata shows a slight increase, and Siphonina reticulata has strong abundance fluctuations (Fig. 7). The trend to a reduction in ostracod diversity, observed in the previous interval, becomes more evident (Fig. 8). The co-occurrence of Argilloecia acuminata with A. kissanovensis, Cythereopteron pinarense, Siphonina reticulata shows a slight increase, and Siphonina reticulata has strong abundance fluctuations (Fig. 7). The trend to a reduction in ostracod diversity, observed in the previous interval, becomes more evident (Fig. 8). The co-occurrence of Argilloecia acuminata with A. kissanovensis, Cythereopteron pinarense, Siphonina reticulata shows a slight increase, and Siphonina reticulata has strong abundance fluctuations (Fig. 7).

CONCLUSIONS

The about 20 meters of sediments cored at Narzole (Piedmont, Northwestern Italy), document an interval extended from the uppermost Messinian Lago-Mare facies to the early Zanclean MP12 foraminiferal zone and MNN12 calcareous nannofossil zone. The Messinian/Zanclean boundary was marked by a dark brown to black barren arenitic layer, as registered in the nearby outcrop of Moncucco, where about all the Zanclean is documented (MP1 to MP4 foraminiferal zones, MNN12 to MNN13/14 calcareous nannofossil zones; Trenkwalder et al., 2008).

The present study confirms that the brackish ostracod assemblage of the uppermost Lago-Mare sediments is referable to the Loxocorniculina dijafarovi biozone (Carbonnel, 1978; Gliozzi et al., 2006) of the upper Messinian post-evaporitic interval. At Narzole, the Lago-Mare biofacies are similar and can be well correlated. Only minor differences within their faunal composition were registered, as the quantitative importance of eutrophic forms as Neogloboquadrinids, suggesting small differences in water productivity of the two areas.

In the basal Argille Azzurre Fm., immediately above the Messinian/Zanclean boundary, the occurrence of outer-neritic to bathyal benthic foraminifers and of deep marine ostracods testifies the sudden re-colonization of the Pliocene Mediterranean Basin after the extinction of the marine fauna during the Messinian Salinity Crisis. The composition of the identified assemblages, made of a typical Mediterranean-Atlantic stock, attests the restored connection between Atlantic and Mediterranean at the very beginning of the Pliocene.

Benthic foraminiferal assemblages show a specific composition very similar to those of early Zanclean deep marine succession of the Mediterranean area (Di Stefano et al., 1996; Sgarrella et al., 1997; Barra et al., 1998; Spezzaferri et al., 1998; Iaccarino et al., 1999; Pierre et al., 2006). Lower percentages of deep bathyal stress-tolerant taxa, associated to high organic fluxes and low oxygen content as Uvigerina peregrina, suggest rather well-oxygenated bottoms and seem to exclude or limit to seasonal fluctuations the strong disaerobic conditions registered at the very base of the Zanclean in southern Sicily (Sgarrella et al., 1997).

All palaeobiological data suggest open marine circulation patterns and epibathyal bottoms during the deposition of the AA Fm. This palaeoenvironmental interpretation is supported by the very high P/(P+B) ratio, the presence of mesopelagic planktonic foraminifers as Sphaeroidinellopsis spp., common to frequent deep cosmopolitan benthic foraminifers (Cibicidoides pseudoungerianus, Sphaeroidina bulloides, Uvigerina peregrina, etc.), common bathyal ostracods (Argilloecia kissanovensis, A. acuminata, Pajienborchella iocosa, Parakrithe dimorpha, Oblitacythereis mediterranea,
Xestoleberis prognata, etc.), the rare discoasterids and ceratholiths (Ceratolithus acatus, Amaurolithus primus, A. delicatus), typical tropical open marine taxa, usually very rare in the Mediterranean Zanclean. Moreover, these data support the hypothesis of deep connections between the Northwestern Italy and the Mediterranean basin during the early Zanclean, allowing the apparently contemporary basin-wide diffusion of planktonic and benthic taxa.

Taking into account the palaeoecological indications given by benthic foraminifer and ostracod assemblages, a basin deepening to about 1000 m could be inferred during the MI1I biozone (ostracod increasing number and diversity, followed by the first influx of S. reticulata and of NADW taxa as C. robertsonianus). A similar palaeoenvironmental change was documented by Trenkwald et al. (2008) and Violanti et al. (in press) in the nearby Monucco outcrop, as well as in the Northern Apennines (Maccarone section; Cossentino et al., 2008).

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